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Virtual reality trajectory of modified PUMA 560 by hybrid intelligent controller

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Article Info	ABSTRACT
	The high performance is a goal for all designers to get better, faster, or more efficient than others. This paper proposes a design for virtual reality (VR) of modified PUMA 560 by hybrid controller between adaptive neuro fuzzy inference system (ANFIS) controller and fractional order proportional, integral, derivative (FOPID) controller. The main purpose is to obtain the optimal trajectory by get the best value of controller's parameters that regulate the manipulator movements smoothly to the desired target. The procedure of design start by obtains the optimal values of the traditional PID controller parameters normally. The next step is applied the FOPID controller with high accuracy. It is high performance to control the perplexing physics system than, the classical integer order of PID controller. The final step to get high performance of the control system under considers is achieved by hybrid between FOPID with ANFIS controller which used the pervious output as predictive point. The whole proposed hybrid controller model was simulated and reproduction by MATLAB Version 2019b and Robotic system Toolbox 9. The optimal design of this controller is applied with 3D model of modified PUMA 560 which design by using VR technique under MATLAB/Simulink.

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1.   INTRODUCTION

Clever control frameworks increment the adequacy of control systems and defeat points of confinement of old style and versatile controllers. They are relied upon to have in-manufactured adjustment/learning and basic leadership capacities to deal with vulnerabilities so the ideal execution can be accomplished [1, 2]. To beat customary figuring worldview limits, specialists search for new computational ways to deal with incomplete displaying of neural framework usefulness and that can take care of certifiable issues viably. Novel computational models have risen, all in all called delicate figuring. Joining insight into delicate figuring are artificial neural system (ANN), fluffy rationale, ANFIS, genetic algorithm (GA), and information-based master frameworks [3-5]. Insightful self-learning or self-arranging control of master frameworks, man-made consciousness or artificial intelligence (AI), fuzzy logic (FL), neural system or neural network (NN), cross breed systems, and so on are the new presentation improving apparatuses of modern force gadgets with drive plant [6]. Fuzzy logic presented by Zadeh with first form in 1965 [7, 8]. It forms information by means of fractional, instead of fresh, set participation. Like neural system, FL can create unmistakable ends from obscure, vague, uncertain, and missing, input data. An appropriate fuzzy inference system (FIS) is basic to rectifying fluffy enrollment capacities and fluffy standards yet building it requires some investment and necessities significant mastery [9-11].

Joining an idea of fuzzy rationale with artificial neural system, it is a cross breed canny framework that improves programmed learning and adjustment. Specialists have utilized such a framework to anticipate and display in different building frameworks. Fundamental to neuro-versatile learning strategies is a fluffy displaying technique that learns a FL at that point gains from the information it is demonstrating. Change of the participation work limits needn't bother with a human administrator, so this is a preferred position over unadulterated fluffy worldview [12-15].

Nonstop and dull assignments of creation many parameters such as: tuning, lines are weakness can produce mishap/damage or long haul medical issues. The robot controller arm can more than once convey immense and substantial parts starting with one generation line then onto the next, so is these days widely utilized in processing plants to build effectiveness and handle rehashed/risky/sensitive undertakings (e.g., semiconductor wafer creation) [16-19].

Repetition of the robot controller can be beneficial when the DOF of a given errand is not as much as that of the controller. At the point when a joint disappointment happens, the robot controller is as yet ready to play out its undertaking dependably. Solitary arrangement of the robot controller can be maintained a strategic distance from by controlling repetition through powerful converse Jacobian peculiarity [20, 21]. To help ANFIS development, fuzzy subtractive bunching groups the accessible information into fuzzy bunches. FL subtractive bunching works superior to does different FIS grouping techniques. Distinctive span mixes create diverse FIS, as shown in Figure 1. Picking the correct powerful to a given issue is along these lines significant [22].

$$R_a^{1} : if \quad x_i \quad is \quad A_1^1 \quad and \quad x_j \quad is \quad A_2^1, \quad then \quad ff_1 = p_A x_i + p_A x_j + r_1 \qquad (1)$$

$$R_a^{2} : if \quad x_j \quad is \quad A_1^2 \quad and \quad x_j \quad is \quad A_2^2, \quad then \quad ff_2 = p_B x_i + p_B x_j + r_2 \qquad (2)$$
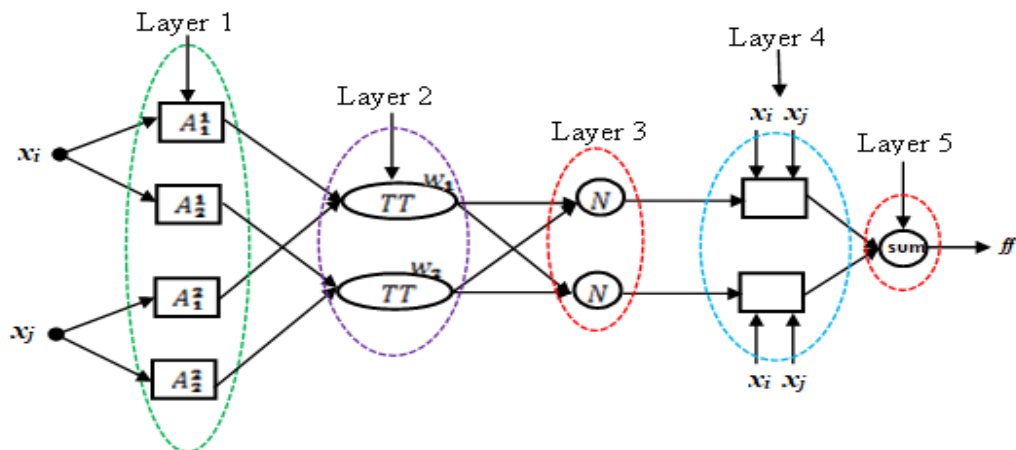

Figure 1. Structure of Sugeno-Takagi FIS based on (12)

2. INVERSE KINEMATIC SOLUTION OF MODIFIED PUMA 560

The measure of joints chooses DOF controller. The normal support in any occasion must have 6 self-ruling DOF: situating has three and three for heading. In cases lass the 6-DOF, the blast can't arrive at a gauge course for each point in its working environment. Applications, for instance, are spreading over around or behind hindrances need more than 6 DOF. Extended connections, apart from this, create control problems (the console with more than six connections is known as the dynamically repeated controller). Workspace is the comprehensive volume that is scanned by the end effector through all possible developments in the console set. It is bound by the control engineering and mechanical limitations of the joints [23-26]. Direct-driving the robot wipes out apparatus issues of backfire, contact, and consistence. The coupling among the connections, in any case, is progressively noteworthy, and the engine elements might be substantially more perplexing. To extricate better from this kind of controller, an alternate arrangement of control issues must be tended to [27].

We presents in this work the proposal of a DMRAC based on ANFIS hybrid with optimized traditional PID controller for a modified PUMA 560 robot, as shown in Figure 2. A balance with controller's shoulder joint marginally confounds with two kinematics solution; forward and inverse. Joint organize outlines are along these lines previously settled by means of DH show (DH parameters are described by Table 1), the Ai matrices can be the calculated as:

$$A_{1a} = \begin{bmatrix} c_{a1} & 0 & s_{a1} & 0 \\ s_{a1} & 0 & -c_{a1} & 0 \\ 0 & 1 & 0 & d_{a1} \\ 0 & 0 & 0 & 1 \end{bmatrix} ; A_{2a} = \begin{bmatrix} c_{a2} & 0 & s_{a2} & a_2 \\ s_{a2} & 0 & -c_{a2} & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_{3a} = \begin{bmatrix} c_{a3} & 0 & -s_{a3} & a_3 \\ s_{a3} & 0 & c_{a3} & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} ; A_{4a} = \begin{bmatrix} c_{a4} & 0 & -s_{a4} & 0 \\ s_{a4} & 0 & c_{a4} & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_{5a} = \begin{bmatrix} c_{a5} & 0 & s_{a5} & 0 \\ s_{a5} & 0 & -c_{a5} & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} ; A_{6a} = \begin{bmatrix} c_{a6} & 0 & s_{a6} & 0 \\ s_{a6} & 0 & c_{a6} & 0 \\ 0 & 1 & 0 & d_{6a} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
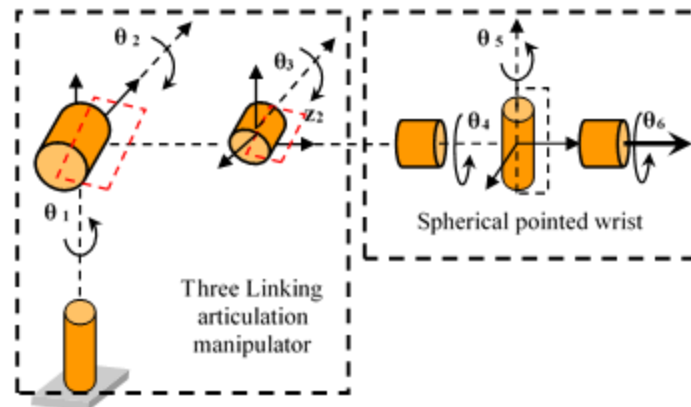

Figure 2. Modified PUMA 560 robot structure

Table 1. The description of DH parameters of the modified PUMA 560 parameters
(* denoted to Joint Variable)

Link	d_i	a_i	α_i	Q_i
L_{1a}	d_{1a}	0	$\pi/2$	Q_{1a}
L_{2a}	0	a_{2i}	0	Q_{2a}
L_{3a}	0	a_{3i}	0	Q_{3a}
L_{4a}	0	$-\pi/2$	0	Q_{4a}
L_{5a}	0	$\pi/2$	0	Q_{5a}
L_{6a}	D_{6a}	0	0	Q_a

The solution of mathematical parameters of trajectory and controller assumed the end-effector with point (o) and its direction with R=(rij), while the wrist center at (o_c), now we can get (3). R presents the direction of the edge $o_6x_6y_6z_6$ comparative with the starting point (base). In the event that parts (o) is the position of final traget are bull up o_x, o_y, o_z while a segment of robot wrist community position are x_{c1}, y_{c1}, z_{c1}, (3) will give this relationship.

$$o_c^o = o - d_{6a}R_a \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}; \quad \& \quad \begin{bmatrix} x_{c1} \\ y_{c1} \\ z_{c1} \end{bmatrix} = \begin{bmatrix} x_{c1} - d_6 r_{13} \\ y_{c1} - d_6 r_{23} \\ z_{c1} - d_6 r_{33} \end{bmatrix} \tag{3}$$

$$
\left.
\begin{aligned}
&q_{11} = a\tan 2(x_{c1}, y_{c1}); \quad q_{31} = \tan^{-1}\left(\frac{\pm\sqrt{1 - D_a^2}}{D_a}\right) \\[2mm]
&where: D_a = \frac{x_{c1}^2 + y_{c1}^2 - d_{a6}^2 + (z_{c1} - d_{a1})^2 - a_2^2 - a_3^2}{2a_2 a_3} \\[2mm]
&q_{21} = \tan^{-1}\left(\frac{z_{c1} - d_1}{\sqrt{x_{c1}^2 + y_{c1}^2 - d^2}}\right); \quad q_{41} = \tan^{-1}\left(\frac{-c_1 s_{23} r_{13} + s_1 s_{23} r_{23} + c_{23} r_{33}}{c_1 c_{23} r_{13} + s_1 c_{23} r_{23} + s_{23} r_{33}}\right) \\[2mm]
&q_{51} = \tan^{-1}\left(\frac{\pm\sqrt{1 - (s_1 r_{13} - c_1 r_{23})^2}}{s_1 r_{13} - c_1 r_{23}}\right); \quad q_{61} = \tan^{-1}\left(\frac{s_1 r_{12} + c_1 r_{22}}{-s_1 r_{11} + c_1 r_{21}}\right) \\[2mm]
&where: \\
&c_{ia} = \cos(q_{ia}), \quad \& \quad s_{ia} = \sin(q_{ia})
\end{aligned}
\right\} \tag{4}
$$

The solution of kinematics is obtained by expository arrangement with course of action of the above conditions. General responses for the upheaval edges are as sketched out underneath. Subbing d_{1a}=20cm, d_{6a}=15cm, a_2=22cm, and a_3=20cm for the target of end-effector and its directions at 20, 40, 10, $\pi/3$, - $\pi/3$, and $\pi/3$ will get the final form in (5). In genuine applications, for the robot to communicate with its condition, an appropriate consistence in Cartesian space must be indicated. Utilization of agreeable, as opposed to solid, position control has likewise been proposed, essentially to keep away from the enormous powers coming about because of a hardened robot arm's contact with nature (particularly if the earth is obscure and unstructured).

$$
\left.
\begin{aligned}
&x_{c1} = 12cm, \ y_{c1} = 25cm, \ z_{c1} = 20cm, \ D = 30cm, \\
&q_{11} = 0.5646 rad, \qquad\qquad q_{21} = 0.6981 \ rad, \\
&q_{31} = q_{31} = 1.3408 \ rad, \qquad q_{41} = -1.9425 \ rad, \\
&q_{51} = 0.3986 \ rad, \qquad\qquad q_{31} = 2.5649 \ rad, \\
&\qquad q_{61} = 5.9832e^{-17} \ rad,
\end{aligned}
\right\} \tag{5}
$$

3.   INTELLIGENT CONTROLLER SYSTEM DESIGN

The design of proposed controller depends on reality and accuracy for invers kinematics solution. The training of intelligent part of ANFIS controller used the real data from kinematic solution. The second part of controller is FOPID was implemented by classical procedure of controller design. It is apply PID controller design with classical analysis of system performance. The fundamental structure of the new controller presents by Figure 3. Displaying of the old style controller can be executed as controller-structure technique (e.g., experimentation). ANFIS controller's underlying condition, wiping out the distinguishing proof fundamental in other versatile control methods.

The ANFIS controllers with FOPID controller yields are added. Post-beginning, the preparation for parameters is identified with ANFIS controller's parameters as demonstrated by fuzzy change getting ready standards (explained straightaway). The old style FOPID controller is tuning the components K_p, K_i, K_d withdrew before utilizing them; they address the concealed arranging states of the proposed intelligent controller.
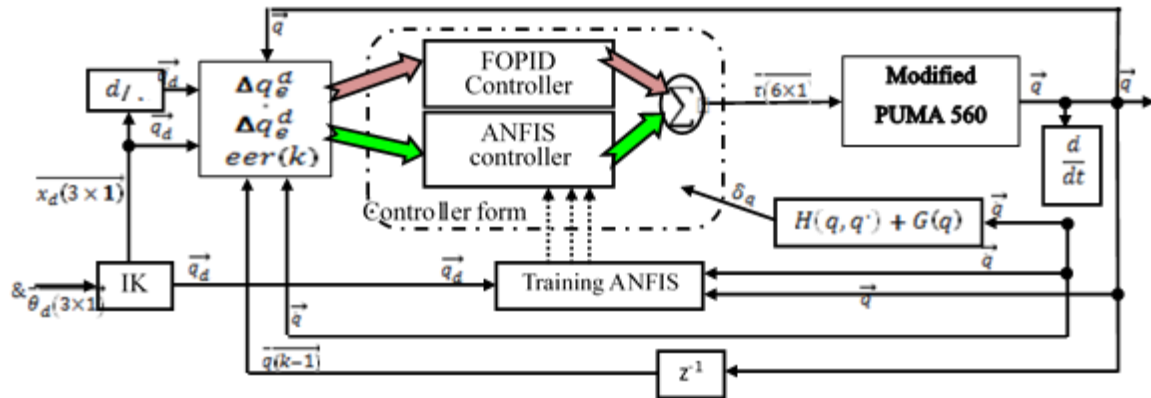
Figure 3. Overall block diagram of hybrid intelligent controller

4. ANIMATION MODEL FOR THE MODIFIED PUMA 560 ROBOT

VRML is one of the most important design programs for 3D objects, coordinating their input and controlling their output based on real physical hypotheses for all system modeling parameters. This program was used in the design of the arm (including) developed in this work because it provides many facilities in the design of these models. The VRML Builder is distinguished by its written software for modeling and training the 6-DOF robot arm and configuring its working environment.

There is a huge difference in the updates that programs are treated with VRML and MATLAB. The coordinates that use VRML, where the coordinate (in y-axis) indicates the top of the triangular model, while the coordinate (in x-axis) represents the left and right of the model, while the coordinate (in z-axis) represents the dimension and proximity to the screen of the VRML program as shown in Figure 4.
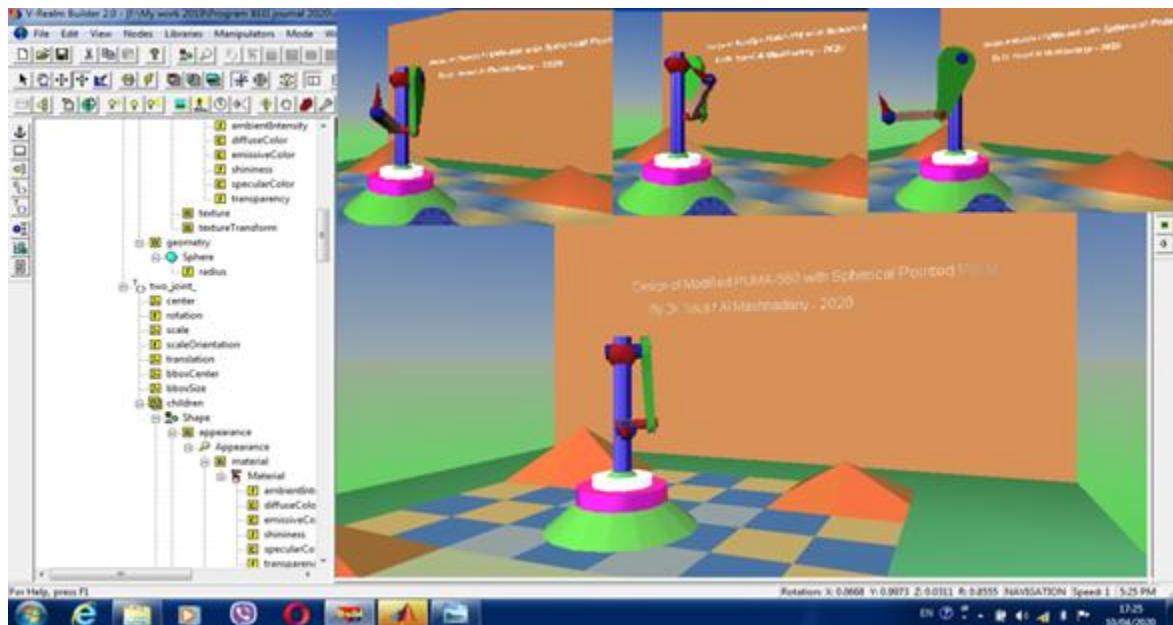

Figure 4. Modified PUMA 560 robot model based on virtual reality enivorment

The design in this work presents in Figure 4, I used the integrated time correlation between virtual reality and the MATLAB program by linking the instructions between the Simulink environment and the triple model in VRML by calculating and configuring orders and linking the implementation of the instructions that are executed through the main processor of the computer with the orders that are implemented in the triple model with quantities and physical measurements that Pre-prepared and calculated at the stage of calculating the mathematical model of the arm.

5. SIMULATION OF PROPOSED DESIGN

The structure proposed by the VR environment was presented by Matlab software Ver. 2019b with Robotic system Toolbox 9. The cloning began by an unshakable quality inspection of the old and half-style ANFIS console (which by chance is faster and more accurate than the conventional console alone). The ANFIS console was tried in half and half on different exchange work models, and its versions were contradictory and the console was in the old style as shown in Figure 5. Model exchange capabilities (T.F) are:

$$T.F.a(s) = \frac{1}{s^2 + 7s + 6} \quad or \quad T.F.b(s) = \frac{1}{s^3 + 12s^2 + 20s + 18} \quad (13)$$
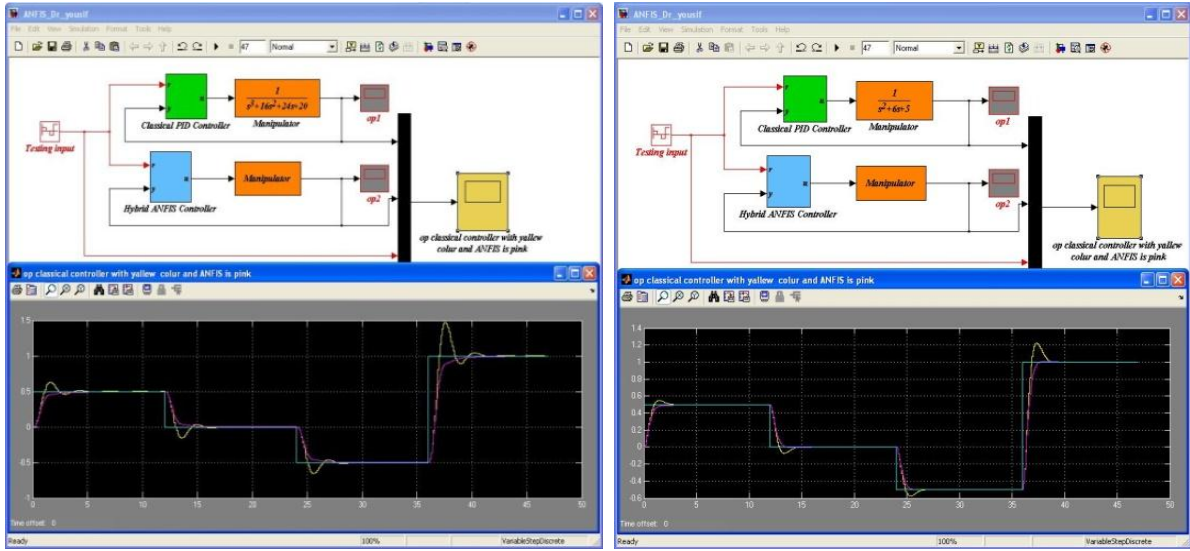

Figure 5. Simulation of proposal design of intelligent controller

The simulation results for proposed design of intelligent controller explained the high performance of system design. it is clear from classical analysis of outputs. The simulation achieved by using practical initialization parameters because the presents of 3D model need the high accuracy of simulation to get accurate trajectory. Figure 6 presents 3D MATLAB simulation of modified PUMA 560 recreation of the IK solution.
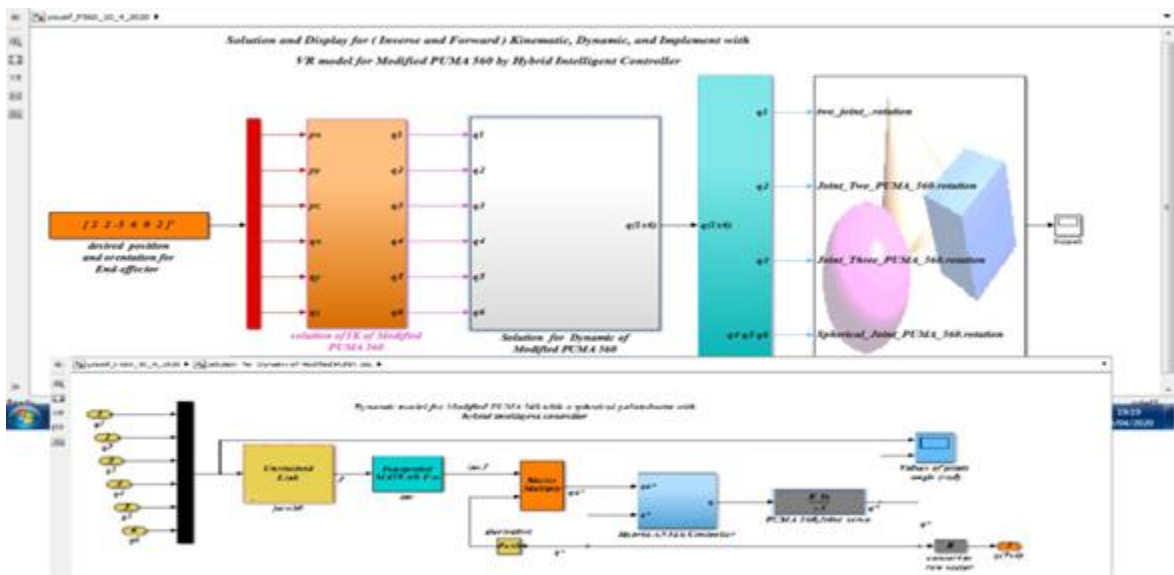

Figure 6. Simulation of Inverse kinematic solution and dynamic response

Figure 7 presents the simulation of VR model for modified PUMA 560 by using the hybrid intelligent controller. The modified PUMA 560 performance testing by checking accuracy of getting the target point by optimal trajectory, the speed of apply the instructions, and the reliability implementation of poroposed resulting by using the hybrid intehhlgent controller. The implementation of trajectory depends on the accuracy of calculation of joints angle for selected job. the results with different complex pathes for modified PUMA 560 improve the ability of consider the setting parameters of this model as practical robot with different application such as industrial, biomedical and eduction. Figure 8 presents different posture and its trajectory, the using spherical pointed gripper offer for this robot to apply high complex tasks and can be depends this model for very accurate applications.
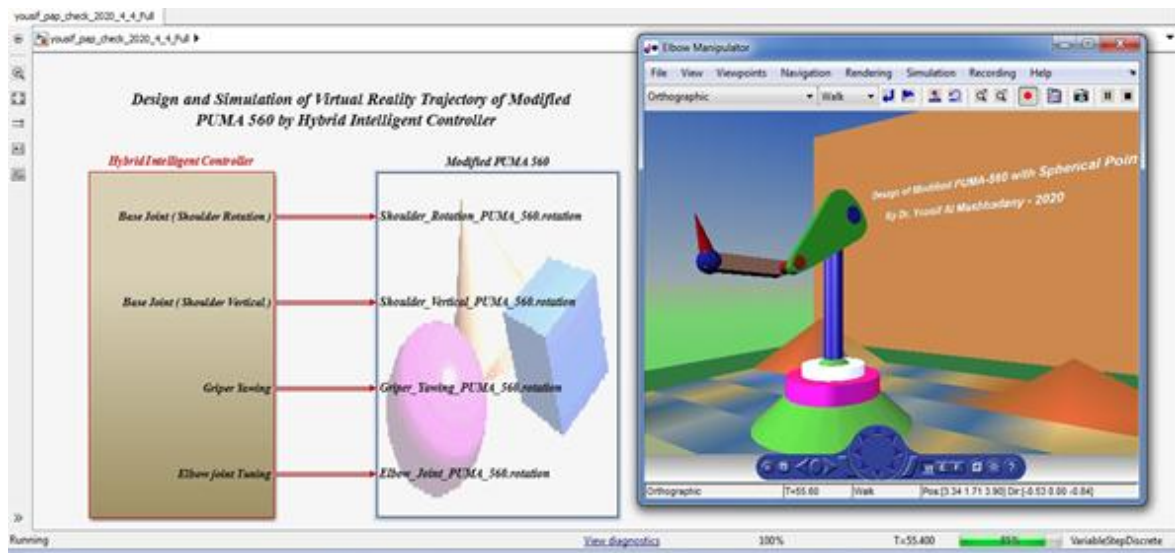

Figure 7. Final simulation form of modified PUMA 560 with hybrid intelligent controller

Figure 8. Postures of the modified PUMA 560 in different trajectories

6.   CONCLUSIONS

The solution of kinematic to get imagining for performance is inferred in D-H documents. Performance of simulation was made by VR technique with MATLAB Var. 2019b by using Robot Tool No.9. Simulated results with optimized hybrid intelligent controller configuration allow checking robot parameters through forward and reverse kinematics. This encourages the structure, development and review of original robots. The high ability to adapt ANFIS controller methodology is appropriate for wide range of control applications in the field of biomedical, industrial, biophysicists process and static-dynamic nuclear control process, it is difficult to obtain a strong, specific brand through direct setup (this exploration uses a direct crossover MRAC and thus can The framework error is constantly limited). The palatable recreation results demonstrate the feasibility of the proposed plot. An examination of the entertainment consequences of

both the usual and semi-linear ANFIS console shows extended framework methods that reduced overtaking and leveling times, resulting in a significant reduction in native implementations. This work crossed the proposed new ANFIS console according to optimized an old style controller in the framework and changing interactions before retrofitting the cross-strain controller in the frame without reproducing the frame to similarity.

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